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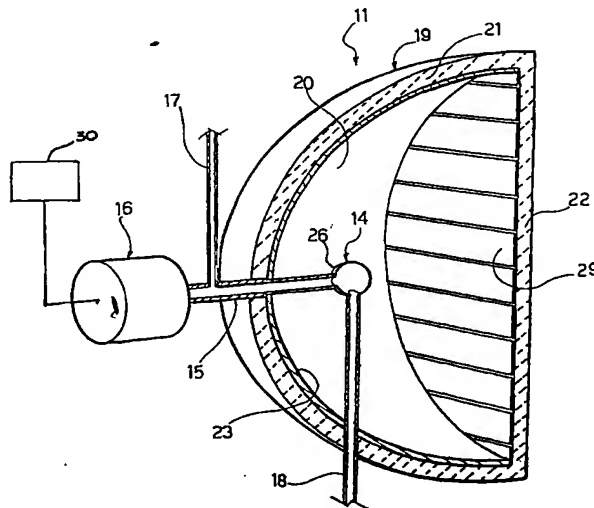
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(54) Title: A MICRO-COMBUSTOR SYSTEM FOR THE PRODUCTION OF ELECTRICAL ENERGY



(57) Abstract: A system for the production of electrical energy, comprising: a combustion chamber (14) made of material that is able to withstand high temperatures, an injection device (16) connected to said combustion chamber (14) by means of an injection conduit (15), means (17) for supplying combustion support substance into the combustion chamber (14) and means (18) for the removal of gaseous combustion products, means (26) for the selective emission of radiation onto the outer surface of the combustion chamber (14). The combustion chamber (14) is enclosed in a conversion chamber (20) within which are maintained sub-atmospheric pressure conditions, so that a substantial part of the heat developed by the combustion reaction is converted into electromagnetic radiation.

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"A micro-combustor system for the production of electrical energy"

* * *

The present invention relates to a micro-combustor
5 system for the production of electrical energy.

The present invention is based on the physical principle whereby thermal energy produced by a combustion is transformed into electromagnetic energy, which in turn is converted into electrical energy, for
10 instance by means of photovoltaic cells made of semiconductor material.

The object of the present invention is to provide a micro-combustor system for the production of electrical energy with high efficiency of conversion of
15 the thermal energy into electrical energy.

According to the present invention, this object is achieved by a system having the characteristics set out in the main claim.

The present invention shall now be described in
20 detail with reference to the accompanying drawings, provided purely by way of non limiting example, in which:

- Figure 1 is a schematic perspective view of a micro-combustor system according to the present
25 invention, and

- Figure 2 is a perspective sectioned view of a conversion device indicated by the arrow II in Figure 1.

With reference to Figure 1, the number 10
30 schematically designates a micro-combustor system for the production of electrical energy. The system 10 comprises a plurality of conversion devices 11, electrically connected to each other in series or in parallel, each of which is constructed as described
35 hereafter. The system 10 comprises a pipeline of

conduits 12 to supply fuel and combustion supporter to the individual conversion devices 11, a pipeline 13 of exhaust conduits for the removal of gaseous combustion products from the conversion devices 11 and a network
5 of electrical connections, for regulating generated power, for the electrical ignition of the combustors and for transporting the current from the combustor to the load resistance.

With reference to Figure 2, each conversion device
10 11 comprises a combustion chamber 14 made of material that is able to withstand high temperature. Preferably, the combustion chamber has spherical shape and is constituted by such material as to withstand temperatures in the order of 1500 - 2000 K.

15 The combustion chamber is preferably provided with means for the selective emission of electromagnetic radiation, preferably made in the shape of a lining 26 applied onto the outer surface of the combustion chamber 14. The combustion chamber is preferably
20 constituted by a material with high heat conductivity (for instance tungsten or molybdenum), to allow the heat generated by combustion to reach the outer surface 26. At least a part of the inner surface of the combustion chamber 14 is preferably coated with a
25 material with low heat conductivity of the meso-porous or nano-porous type with porosity coated by catalysing agents, having the function of lowering the combustion activation temperature and reducing emissions of
30 polluting reaction products (for instance nitrogen oxides). The material with low heat conductivity can be interleaved with the material with high heat conductivity in the form of a composite.

The lining 26 preferably has a selective emissivity in a wavelength band of a few hundredths of
35 nanometres. The lining 26 can for instance be

constituted by a micro-structure obtained directly on the outer surface of the combustion chamber, or a thin layer of oxide having a highly selective spectral emission (oxide of yttrium, thorium, cerium, europium, 5 erbium, terbium, ytterbium or other rare earth).

The combustion chamber 14 communicates with a fuel injection conduit 15, with a conduit 17 for supplying the combustion support and with a conduit 18 for the exhaust of gaseous reaction products. The conduit 15 10 preferably has cylindrical shape with a conical terminal segment, in proximity to the micro-injection system 16, with a section that increases outwardly; the purpose of the conical terminal section is to assure that the combustion support substance is aspirated by 15 Venturi effect. The conduits 15, 18 are preferably constituted by ceramic material, or other material with low heat conductivity, to prevent the heat of the combustion chamber to propagate by thermal conduction to the exterior. The outermost part of the exhaust 20 conduit 18 is preferably metallic to allow exhaust gases to release their residual heat before leaving the conversion chamber. The conduit 15 may have an articulated shape, for instance a spiral or a coil, to prevent the combustion products from returning towards 25 the micro-injector. Similarly, the exhaust conduit 18 can have articulated shape to favour the cooling of the combustion products. The supply conduit 17 is preferably connected to the injection conduit 15; alternatively, it can be connected directly to the 30 combustion chamber. The conduit 17 for supplying the combustion supporting substance can be eliminated if a mixture of fuel pre-mixed with liquid or gaseous combustion supporting substance is injected into the injection conduit 15.

The combustion chamber 14 is closed and it does not exchange gaseous products with the exterior except through the conduits 15, 17 and 18.

Each conversion device 11 is provided with a
5 micro-injection device 16 preferably constituted by an
ink-jet injector, of the "bubble" type or of the
piezoelectric type, able to inject drops of fuel or a
combustion-support substance mixture of a volume of a
few picolitres and with a frequency which can be
10 controlled by means of a controller (30) from a few kHz
to hundreds of kHz. Alternatively, if a gaseous fuel is
used, the injection system can be constituted by a
miniaturised Bunsen burner. The fuel injected by the
injection system 16 penetrates inside the combustion
15 chamber 14 through the injection conduit 15.
Preferably, the gaseous fuel injected by the injection
device 16 is selected within the group comprising:
methane, propane, butane, hydrogen, natural gas or
other fuels including the possibility of adding
20 metallic particles to the fuel.

Each conversion device 11 comprises a hollow
structure 19 forming a sealed conversion chamber 20,
within which is obtained a vacuum or is contained an
inert gas at low pressure. The combustion chamber 14 is
25 located inside the conversion chamber 20 and the
conduits 15, 18 extend through the walls of the hollow
structure 19. The walls of the hollow structure 19
defining the conversion chamber 20 can be made of
metal, if a vacuum is obtained in the hollow structure
30 19, or of ceramic material coated with a high
reflectance layer, in all other cases.

The hollow structure 19 comprises an elliptical
wall 21 and a planar wall 22, so the conversion chamber
20 has the shape of a rotational semi-ellipsoid with
35 half-axes A and B. The dimensions of the axes of the

conversion chamber 20 may vary from a minimum of 3 to 50 times the diameter of the combustion chamber 14. The combustion chamber 14 is preferably positioned in the first focus of the elliptical surface. The inner
5 surface of the elliptical wall 21 is preferably provided with a lining 23 having high reflectance over the entire emission spectrum of the source of radiation.

The planar wall 22 of the hollow structure 19
10 bears means for converting electromagnetic energy into electrical energy, schematically designated by the reference number 24. Said conversion means are preferably constituted by photovoltaic cells made of semiconductor material, preferably with a band gap in
15 the order of 0.5 - 0.8 eV in order to maximise the conversion efficiency by Planck radiation with colour temperature of 1500 - 2000 K. In a preferred embodiment, the photovoltaic cell is of the Schottky type and the active junction is constituted by silica
20 and aluminium. In the case of the selective electromagnetic energy the material of the cells 24 constituting the conversion means is selected in such a way that the band gap energy is slightly greater than the energy of the photons corresponding to the
25 wavelength of maximum emission, in order to maximise the conversion efficiency at that wavelength.

The exterior face of the conversion means 24 is preferably coated by a reflective metal layer. The inner wall of the conversion means 24 can be coated by
30 a layer operating on the electromagnetic radiation as a band pass filter. Said layer can be a multi-layered dielectric coating, a metallic coating at the percolation state, an anti-reflection micro-structure (for instance a grid with sub-wavelength period) or a
35 photonic crystal.

The conversion means 24 are positioned in correspondence with the plane that is perpendicular to the greater axis of the ellipsoid and passing through the centre of the ellipsoid, in such a way that the radiation emitted by the combustion chamber 4 reaches the photovoltaic means uniformly. Moreover, also by means of the selected geometry, the radiation not absorbed by the conversion means 24 is reflected by the reflecting rear face or by the front surface of the photovoltaic cell 24 and falls back onto the combustion chamber 14 where it is absorbed.

The particular geometry of the conversion chamber 20 causes both the radiation emitted by the combustion chamber and reflected by the photovoltaic chamber 24, and the radiation emitted by the combustion chamber 14 and reflected by the inner walls of the semi-ellipsoid to be concentrated on the combustion chamber 14. This assures a maximum recycling of the electromagnetic energy within the conversion chamber and hence a minimisation of fuel consumption and a maximisation of overall conversion efficiency. The radiation reflected by the inner surface of the semi-ellipsoid or by the photovoltaic cell 24 is re-absorbed by the lining 26 with the same efficiency with which it is emitted thereby.

The heat developed by the fuel-support substance reaction warms the surfaces of the combustion chamber and is wholly converted into electromagnetic radiation. The dimension of the conduits 15, 18 extending within the conversion chamber 20 is such as to minimise the transfer of thermal energy by conduction between the combustion chamber 14 and the hollow structure 19. The radiation emitted inside the conversion chamber 20 impacts on the conversion means 24 which convert electromagnetic radiation into electric energy. The

electrical power generated by each conversion device 11 can vary from a few watts to some tens of watts. Each device 11 is provided with electrical contacts (not shown herein) which collect electrical energy produced
5 by the semiconductor cells 24.

Maintaining a vacuum or sub-atmospheric pressure conditions inside the combustion chamber 20 allows to reduce the quantity of thermal energy dispersed by convection. Consequently, nearly all the heat developed
10 by the combustion reaction is converted into electromagnetic radiation which in turn is converted into electrical energy by the conversion means 24. To obtain a vacuum or low pressure conditions within the conversion chamber 20, various known techniques for
15 assembling components in a vacuum may be used.

CLAIMS

1. A portable device for the production of electrical energy, comprising a matrix of one or more conversion modules (11), operating in series or in parallel, each of which comprises:
- a combustion chamber (14) made of material that is able to withstand high temperatures,
 - an injection device (16) connected to said combustion chamber (14) by means of an injection conduit (15),
 - a controller (30) of the injection frequency and hence of generated power,
 - means (17) for supplying combustion support substance into the combustion chamber (14),
 - means (18) for the removal of gaseous combustion products,
 - means (26) for the selective emission of radiation onto the outer surface of the combustion chamber (14)
 - means (24) for the conversion of radiant energy into electrical energy,
 - means for igniting the combustion reaction,
- characterised in that the combustion chamber (14) is enclosed in a conversion chamber (20) within which are maintained sub-atmospheric pressure conditions, so that a substantial part of the heat developed by the combustion reaction is converted into electromagnetic radiation.
2. A system as claimed in claim 1, characterised in that the combustion chamber (14) has substantially spherical shape and in that the conversion chamber (20) has semi-ellipsoidal shape, with the combustion chamber (14) positioned in correspondence with a first focus of the ellipsoid.

3. A system as claimed in claim 2, characterised in that said conversion means (24) are positioned on a planar surface that is perpendicular to the greater axis of the ellipsoid and passes through the centre of the ellipsoid itself.

4. A system as claimed in claim 1, characterised in that said means (24) for the conversion of radiant energy into electrical energy comprise a plurality of photovoltaic cells.

5. A system as claimed in claim 1, characterised in that said means for the selective emission of radiation have a narrow emission band with a peak in correspondence with the wavelength at which the conversion means (24) have the maximum conversion efficiency.

6. A system as claimed in claim 1, characterised in that said means for the selective emission of radiation comprise a lining (26) applied onto the outer surface of the combustion chamber (14), said lining being constituted by a material selected in the group comprising: micro-structure metal, metallic or dielectric photonic crystal, oxide or mixture of oxides of rare earths.

7. A system as claimed in claim 1, characterised in that the outer surface of the combustion chamber (14) has such a total area that the radiant energy emitted by the emission means (26) is equal to the sum of the total thermal energy developed by the combustion reaction at steady state and of the fraction of radiant energy that is reflected by the inner walls of the conversion chamber or by the conversion means (24) and reabsorbed by the combustion chamber (14).

8. A system as claimed in claim 1, characterised in that said conversion chamber (20) has axes whose

size ranges between 3 and 50 times the diameter of the combustion chamber.

9. A system as claimed in claim 1, characterised in that said injection device (16) is a head of the
5 ink-jet type.

10. A system as claimed in claim 9, characterised in that said injection head is of the "bubble" ink-jet type.

11. A system as claimed in claim 9, characterised
10 in that said injection head is piezoelectric.

12. A system as claimed in claim 1, characterised in that the combustion chamber (14) is constituted by material with high thermal conductivity and able to withstand high temperatures.

13. A system as claimed in claim 12, characterised
15 in that part of the inner surface of the combustion chamber (14) is coated with a porous layer of material with low thermal conductivity and able to withstand high temperatures.

14. A system as claimed in claim 13, characterised
20 in that the porosities of said porous layer are coated by a catalysing material serving the purpose of lowering the activation temperature of the combustion reaction and of limiting the generation of noxious
25 combustion products.

15. A system as claimed in claim 12, characterised in that the combustion chamber (14) is made of metallic material.

16. A system as claimed in claim 15, characterised
30 in that said metallic material is constituted by tungsten or molybdenum.

17. A system as claimed in claim 1, characterised in that said injection conduit (15) and said means (17) for supplying the combustion support substance and said

means (18) for extracting the combustion gases are made of a material with low thermal conductivity.

18. A system as claimed in claim 17, characterised in that the outermost segment of the exhaust conduit
5 (18) is made of a material with high thermal conductivity to allow combustion products to yield the residual heat before exiting the conversion chamber.

19. A system as claimed in claim 1, characterised in that the injection conduit (15) and the means (17)
10 for injecting the combustion support substance independently end into the combustion chamber (14).

20. A system as claimed in claim 1, characterised in that the means (17) for the injection of the combustion support substance end into the injection
15 conduit (15) before entering the combustion chamber (14).

21. A system as claimed in claim 1, characterised in that the conversion chamber (20) is formed within a structure (19) made of optically polished metallic
20 material.

22. A system as claimed in claim 1, characterised in that the conversion chamber (20) is defined within a structure (19) made of plastic or ceramic material and coated with a layer (23) of material with high
25 reflectance.

23. A system as claimed in claim 4, characterised in that the surface of said photovoltaic cells facing the interior of said conversion chamber (20) is coated with an optical lining operating on the long
30 wavelengths of the electromagnetic radiation as a band pass filter with transmittance peak in correspondence with the wavelength at which the photovoltaic cells have the maximum conversion efficiency.

24. A system as claimed in claim 4, characterised in that said photovoltaic cells are based on Schottky junctions.

25. A system as claimed in claim 24, characterised in that said Schottky junctions are made of silica and aluminium.

26. A system as claimed in claim 23, characterised in that said optical lining is made of a material selected from the group comprising: multilayer dielectric lining, metallic lining at the percolation state, metallic photonic crystal, anti-reflection micro-structure.

27. A system as claimed in claim 1, characterised in that the injection device (16) is constituted by a miniaturised Bunsen burner.

28. A system as claimed in claim 17, characterised in that the gaseous fuel injected by said injection device (16) belongs to the group comprising: methane, propane, butane, hydrogen, natural gas.

29. A system as claimed in claim 1, characterised in that the exhaust conduit (18) is internally coated with catalysing material able to neutralise the noxious products of the combustion reaction.

30. A system as claimed in claim 1, characterised in that the exhaust conduit (18) has an articulated path in order to favour the cooling of the exhaust gas.

31. A system as claimed in claim 1, characterised in that the injection conduit (15) has an articulated path in order to prevent the combustion products to return towards the injection means.

32. A system as claimed in claim 1, characterised in that said ignition means are electrical and the combustion is started by an electrical discharge, by a spark or by an incandescent filament.

33. A system as claimed in claim 1, characterised in that vacuum is obtained inside the conversion chamber (20).

34. A system as claimed in claim 1, characterised
5 in that inside the conversion chamber (20) is contained an inert gas at sub-atmospheric pressure.

35. A system as claimed in claim 33, characterised in that the conversion chamber is constituted by optically polished metallic material.

10 36. A system as claimed in claim 33 o 34, characterised in that the conversion chamber is constituted by optically polished ceramic material.

37. A system as claimed in claim 1, characterised
15 in that the inner wall of the conversion chamber is coated by layer having high reflectance over the whole spectrum of the radiation emitted by the emission means (26).

FIG. 1

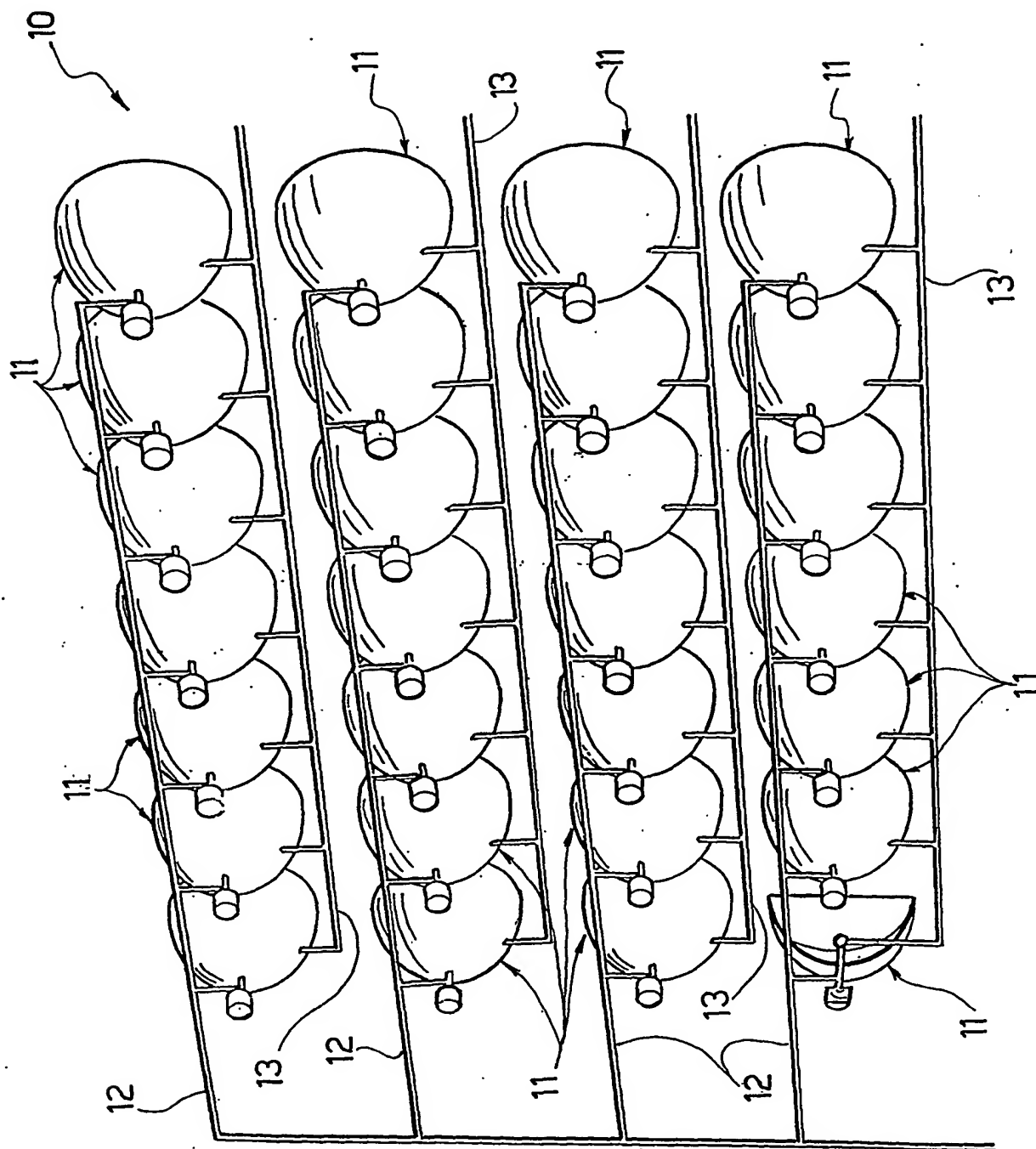


FIG. 2

